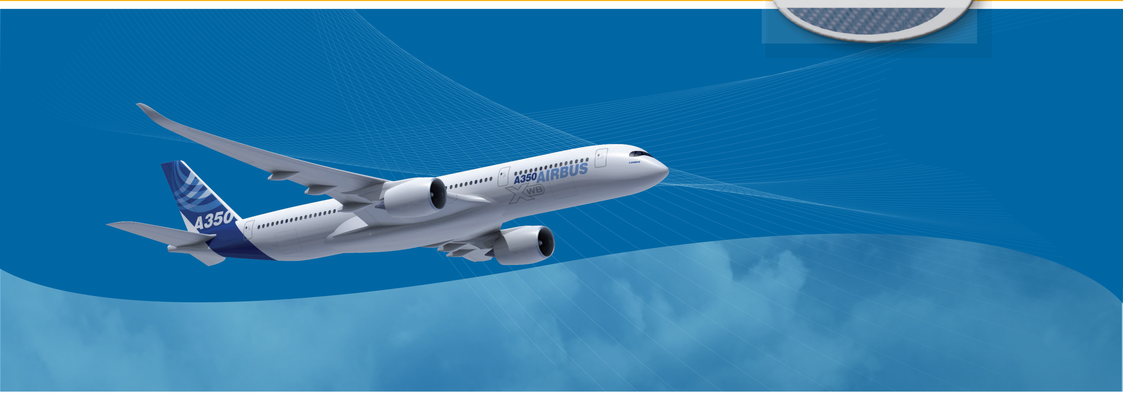
EXTENDED NON-DESTRUCTIVE TESTING OF COMPOSITE BONDS

Optimum bonding solutions for light-weight aircraft structures

ENCOMB



PROJECT OVERVIEW

ENCOMB provides advanced non-destructive testing (NDT) methods for pre and post-bond inspection of CFRP aircraft structural components in order to establish a reliable quality assurance concept for adhesive bonding. State-of-the-art NDT techniques have been screened and the most suitable ones were further developed and adapted to important application scenarios with regard to aircraft manufacturing and in-service repair.

IDENTIFICATION OF FACTORS INFLUENCING ADHESIVE BOND QUALITY

Five application scenarios were identified to be of primary importance for the aircraft manufacturers along with the requirements for extended NDT technologies applying to each scenario.

QUALITY ASSESSMENT OF ADHEREND SURFACES

- Detection of **hydraulic fluid/water** contamination — HF
- Detection of **release agent** contamination — RA
- Detection of **moisture** contamination — MO
- Detection of **thermal damage** of CFRP — TD

QUALITY ASSESSMENT OF ADHESIVE BONDS

- Detection of weak bonds due to **release agent** contamination — RA
- Detection of weak bonds due to **moisture** contamination — MO
- Detection of weak bonds due to **poorly cured** adhesive — PC

QUALITY ASSESSMENT OF ADHEREND SURFACES & ADHESIVE BONDS

Pre and post-bond quality assessment is based on the physico-chemical characterisation of adherend surfaces and adhesive bonds. To this aim reference samples were manufactured for the development of methods. Strict requirements in terms of raw materials, geometry, manufacturing process, adherend surface treatment and bonding process were followed throughout the manufacturing process to ensure minimal deviation in terms of quality of the produced samples and enhance the reliability of the tests.

Adherend surfaces were characterised with conventional laboratory analysis methods (spectroscopic and optical techniques, contact angle measurements) to analyse their physico-chemical properties resulting from sample preparation.

Adhesively bonded samples were characterised with conventional NDT techniques (ultrasonic and x-ray inspection, µ-CT) to analyse their structural integrity resulting from sample preparation.

Mechanical tests were performed on the adhesively bonded samples in order to determine the influence of sample treatment on their mechanical performance. These tests comprised interlaminar fracture toughness and double-lap shear tests.

SCREENING, ADAPTATION & VALIDATION OF ADVANCED NDT TECHNIQUES

Advanced NDT technologies for the detection of selected physico-chemical properties of CFRP adherend surfaces and the quality of the adhesive bonds were identified, verified, developed, adapted, and validated for their potential to comply with the application scenarios and requirements.

Adherend surface quality

METHOD	PARTNER	Step 1 Scenarios HF	RA	MO	TD	Step 2 Scenarios HF	RA	MO	TD
X-ray fluorescence spectroscopy	IFAM	√	–	–	–	now used as reference methods			
Infrared spectroscopy	IFAM	√	–	√	√				
Reflectometry/Ellipsometry	IFAM	–	–	–	–				
Laser scanning vibrometry	IMP PAN	√	√	√	√		+	++	
Optically stimulated electron emission	IFAM	√	√	–	√		++	+	
Infrared spectroscopy	RECENDT	√	√	√	√		+	++	
Active thermography (for Tg analysis)	IFAM	–	–	√	–		–	–	
Aerosol wetting test	IFAM	√	√	–	√		++	–	
Infrared spectrometry	AGILENT	√	–	√	√		–	++	
Laser induced breakdown spectroscopy	IFAM	√	√	–	–		++	–	
THz / GHz reflectometry	IRE NASU	√	√	–	√		–	–	
Optical fibre sensors	EPFL	√	–	√	–		–	+	
Electrochemical impedance spectroscopy	IFAM	√	–	√	–		–	+	
Electronic nose technology	ENEA	√	–	–	–		+	+	
Dual-band active thermography	IZFP	–	–	–	–		–	+	
Vibrothermography	IMP PAN	–	–	–	–		–	–	
THz technology	RECENDT	–	–	–	–				
Optical coherence tomography	RECENDT	–	–	–	–				
Nuclear magnetic resonance	IZFP	–	–	–	–				

Adhesive bond quality

METHOD	PARTNER	Step 1 Scenarios RA	MO	PC	Step 2 Scenarios RA	MO	PC
Active thermography using ultrasonic excitation	EADS-D	–	–	–			
THz / GHz reflectometry	IRE NASU	–	–	–	–	–	
Nonlinear ultrasound	UnivBris	√	–	–	++		
LASAT technique	CNRS				++	+	
Laser ultrasound	RECENDT	–	–	–	–	–	
Active thermography using optical excitation	IZFP	√	√	–	+	+	
Laser scanning vibrometry	IMP PAN	–	√	–	+	++	
Electromechanical impedance	IMP PAN	√	√	√	++	+	
Vibrothermography	IMP PAN	–	–	–	–	–	
Ultrasonic frequency analysis	EADS-D	–	√	–	+	+	
Laser ultrasound	EADS IW F	–	–	–	–	–	
Active thermography (for Tg analysis)	IFAM	–	–	–			

NDT method development is being carried out in two steps:

a. The first comprised a simple comparison of treated samples with a clean reference for all scenarios as a rough screening for principal suitability of the NDT technologies.

b. The second step is dedicated to optimising those technologies with demonstrated suitability by means of samples with different contamination levels down to threshold levels of insignificant impact on bond strength.

This work is completed for a subset of two application scenarios (results shown in the tables) and for the remaining three investigations are in progress (blank fields).

√ : Clear detection of contaminant, differentiable from reference surface state.
++ : Clear detection of contaminant, correlation with contamination level
\+ : Clear detection of contaminant, no correlation with contamination level
– : No differentiation from reference state

DEVELOPMENT OF A QUALITY ASSURANCE CONCEPT

IN-LINE AND IN-SERVICE QUALITY CONTROL

WHO WE ARE

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